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U. S. NAVAL PROVING GROUND

DAHLGREN, VA.

REPORT NO. 4-43

EXAMINATION OF A JAPANESE 8-INCH COMMON PROJECTILE

March 12, 1943.

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NAVAL PROVING GROUND
Dahlgren, Virginia

REPORT NO. 4-43, March 12, 1943.

EXAMINATION OF A JAPANESE 8-INCH COMMON PROJECTILE

NAVAL PROVING GROUND CAPTURED ENEMY EQUIPMENT

REPORT NO. 59.

APPROVED:

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PREFACE

AUTHORIZATION

Specific **directives for this investigation were** issued in Buord ltr Op-16-Z L11-1/EF74 of December 30, 1942.

OBJECT

~~To make~~ a complete chemical and metallurgical examination of fragments was made from a major caliber Japanese projectile ~~(GEE No. 403)~~; ~~and if possible to make a reconstruction of the projectile~~.

SUMMARY

These fragments were ~~have been~~ identified as parts of an 8-inch common projectile having a flat nose and a small conical cap. It appears that this cap can easily be lost on water impact thus transforming an otherwise conventional projectile into a flat-nosed projectile with a predictable under water trajectory. The weight of the loaded and fuzed projectile has been calculated to be 251 pounds of which 7% comprises the bursting charge.

It is shown that this projectile was forged from a small ingot of chrome-nickel electric furnace steel, annealed, rough machined and given a conditioning heat treatment. After conditioning, the projectile was decrementally hardened.

The projectile carried a fuze of the impact delay type, having a simple design and functioning by shear pin action. Molten brass is used to braze the knobbed head of the firing pin between two brass shear plates which are firmly fixed in the fuze body. On impact this knob shears past the cast metal thus allowing the pin to move forward to strike the primer.

A complete reconstruction and a drawing of this fuze is presented.

The gun which fired this projectile had a deep hook-section rifling with uniform twist. A complete description of the rifling is presented together with a comparison with various United States 8-inch naval guns.

Following the completion of this investigation, fragments of a similar projectile were received. The fragments of this latter projectile confirm the reconstruction presented by this report.

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[illegible] Photo No. 607 (A[illegible]) - Examination of Metals from Enemy Weapons. Report No. 59. Fragments of a Japanese 8-inch common projectile as received. CMR 403. The small fragment in the foreground was identified as [illegible] plate.
4 February, 194[illegible].

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NPG PHOTO NO. 609 (APL) - Examination of Metals from Enemy Weapons.
Report No. 59. Nose and cap of a Japanese 8-inch common projectile;
as received. CEE403.
4 February, 1943.

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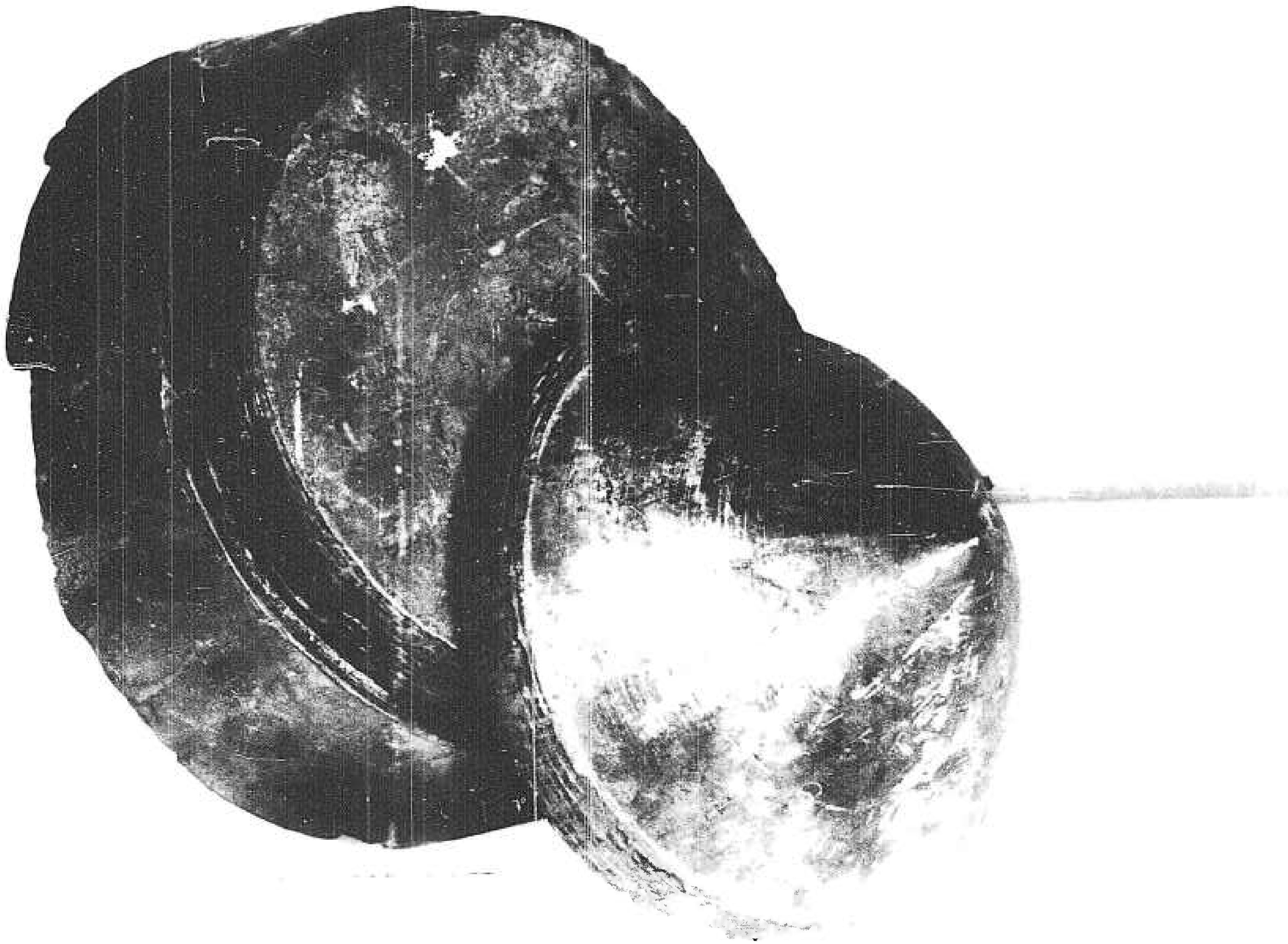
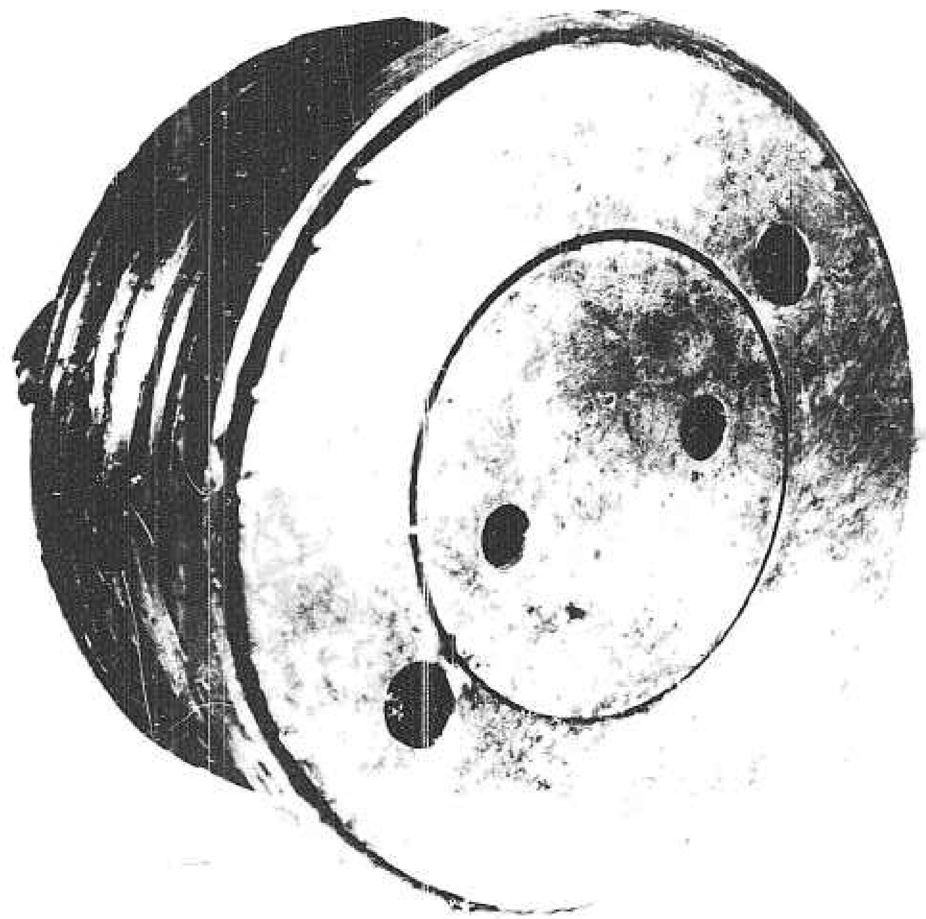


NRC PHOTO NO. 608 (APL) - Examination of Metals from Enemy Weapons. Report No. 59. Base plug from a Japanese 8-inch common projectile; as received. CEM483.
4 February, 1943.

- CONFIDENTIAL -



I INTRODUCTION

The U. S. S. SALT LAKE CITY was struck by a major caliber projectile in an encounter with the enemy in the Pacific area. The attack was carried out at 5000 yards range and 060 relative bearing. The projectile struck at Frame 48, 14 inches above the second deck and penetrated one layer of 35 pounds STS backed by 18 pounds HTS, struck the second deck 66 inches along the line of flight and ruptured two deck platings for a distance of 5 feet (40 lbs. STS) then continued to strike a longitudinal channel 10" x 3.45" x 3.45" (21.9 lbs. STS) 3 inches below the second deck. The projectile was stopped at this point and it fell striking the flange of an "I" beam and the top of the under bottom tank where it exploded. The distance from impact to explosion was 40 feet. The penetration was "clean hole" with edges bent in-board.

The fragments from this projectile were forwarded to the Naval Proving Ground for examination; Fig. 1, NPG Photo No. 607 (APL) shows the nature of the fragmentation and condition of these fragments when received by the Armor and Projectile Laboratory. Fig. 3, NPG Photo No. 609 (APL) shows a detailed view of the peculiar flat nose and pointed cap of this projectile; these two components together with the base plug (Fig. 2, NPG Photo No. 608 (APL)) were recovered practically undamaged. The following markings were found on the projectile:

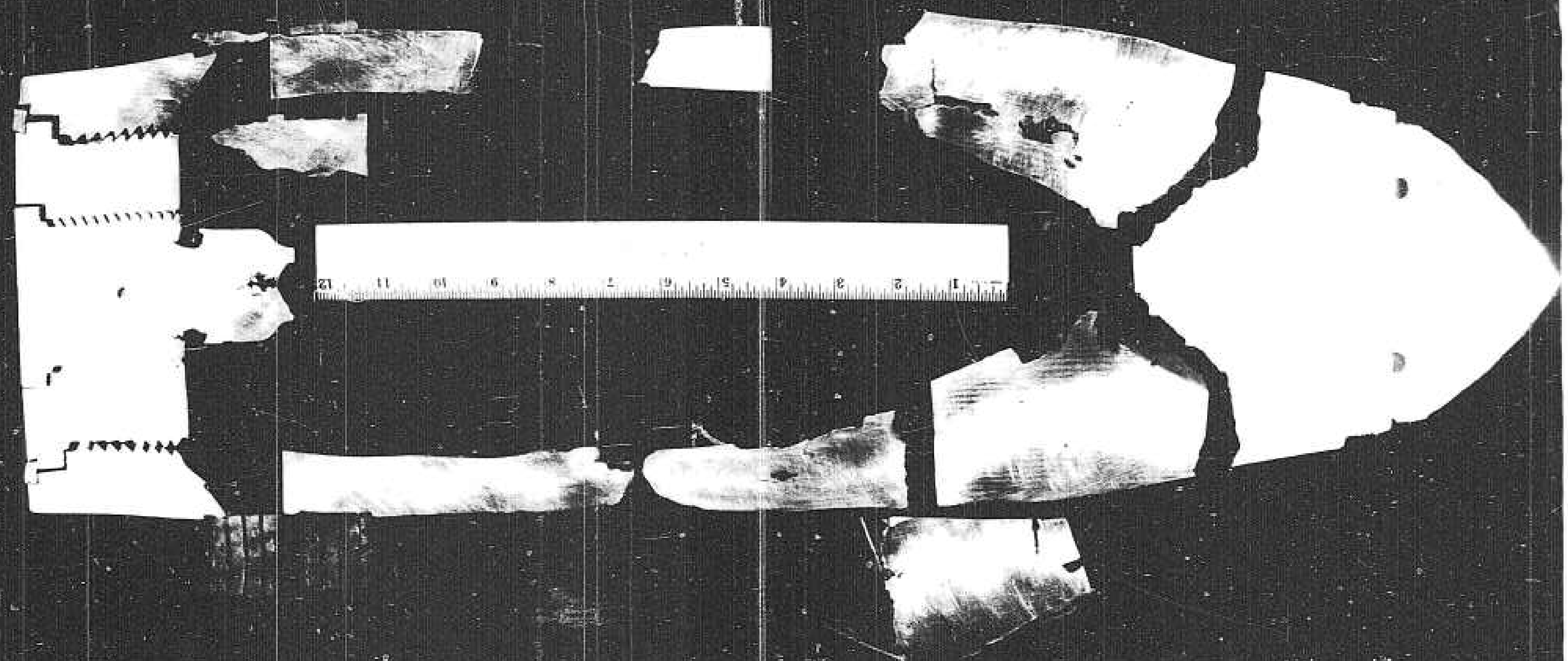
Cap:	7 AP, 14-6-10, 2448
Base Ring:	NCS 9486
Base Plug:	NCS 9486
Booster Adapter:	45485

II INVESTIGATION OF PROJECTILE

(A) RECONSTRUCTION

The first phase of the investigation consisted of cutting selected fragments into slices representative of their original cross section. Fig 4, NPG Photo No. 630 (APL) shows the complete assembly of slices from which further data was obtained. From this assembly the projectile was definitely identified as being of 8-inch caliber and as having a large bursting charge.

The cap and nose are seen to have conjunctive flat surfaces devoid of interlocking; the stud holes in the cap attest that the probable method of assembly was to screw the cap into the windshield fol-



Neg. [illegible] Report [illegible]
assembly of [illegible] with the cross-sectional outline of the pro-
jectile. The [illegible] fragment indic[illegible] of the [illegible]
17 February, 1945. - CONFIDENTIAL -

lowed by screwing the windshield plus cap to the nose - thus the cap is retained to the nose solely by the windshield ring. Further interesting features are the use of two rotating bands and of boat tailing. It was noted that these rotating bands showed practically no fringing.

NPG Drawing 101 (APL) gives a complete reconstruction of this projectile (inside back cover). All dimensions which are given without qualification have been accurately determined by actual measurement; dimensions which have been arrived at by analogy are described as being "approximate".

By reference to Fig. 4, NPG Photo No. 630 (APL) it can be seen that the dimensions from the tip of the cap to the center of the body are accurately ascertainable.

Continuation of the nose profiling to the profiling on the first fragment was used to determine the position of this fragment and the distance from the nose to the forward bourrelet tracing. The side fragment gives a complete cross section of the bourrelet (length of the bourrelet is indicated by arrows); thus allowing the third fragment to be accurately located, since its forward part shows the bourrelet back tracing.

The dimensions from the base to the center of the body could likewise be accurately ascertained. The base ring is complete and includes a portion of the rear band score notch, thus allowing accurate locating of the rotating bands. The distance between rotating bands is given by the fragment which carries both band score notches - the position of the adjoining body fragment is thus fixed.

All dimensions of the projectile were therefore accurately obtained, with the exception of the overall body dimensions. The body dimensions noted on the drawing were arrived at by analogy and by further considerations of profiling; while these are admittedly approximations, it is believed that they are fairly accurate.

Calculations made to determine the weight and capacity of this projectile are given in Appendix (A). The total weight was found to be approximately 251 pounds.

(B) CHEMICAL ANALYSIS

The analyses reported here have been obtained spectrochemically with the exception of those of carbon, phosphorus and sulphur which were determined by standard chemical procedures.

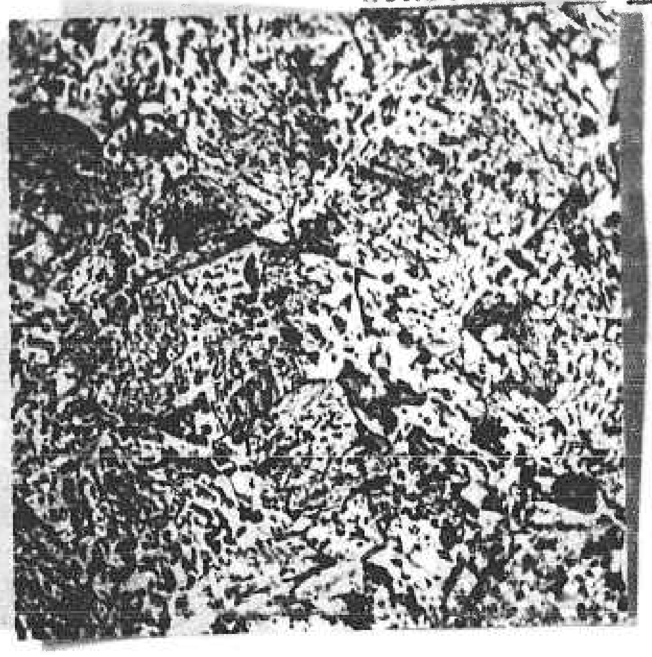
	C	P	S	Mn	Si	Cr	Ni
Cap	.61	.007	.005	.20	.25	2.18	2.87
Body	.63	.007	.004	.20	.25	2.15	2.80
Base Plug	.26	.026	.027	.65	.30	.62	3.30
Fuze Adapter	.30	.010	.007	.48	.22	.67	3.60
Rotating Bands				Pure Copper			
Gaskets				Pure Copper			

Spectrochemical analysis showed no traces of molybdenum, vanadium, tungsten, titanium, copper, boron or zirconium in any of these steels. The very low phosphorus and sulphur content of these steels indicate they were made by electric furnace practice.

(C) MACROETCHING

Etching with hot acid showed that this projectile has exceptional soundness and freedom from segregation of non metallics. The lack of definite flow lines and the presence of small dendrites indicate that the projectile was forged from a small ingot and the cavity was formed by boring.

STRUCTURE OF BASE PLUG.



Carbides in a matrix of ferrite.

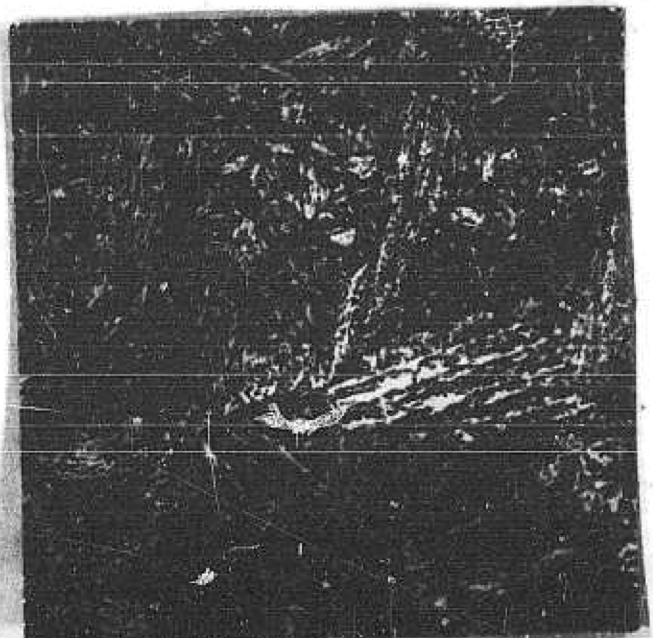
HARDNESS 24 R.C.

MAGNIFICATION 700X

ETCHED: Picral + Nital

Photomicrograph M47

STRUCTURE OF FUZE ADAPTER.



Carbides in a matrix of ferrite. Quench and temper structure.

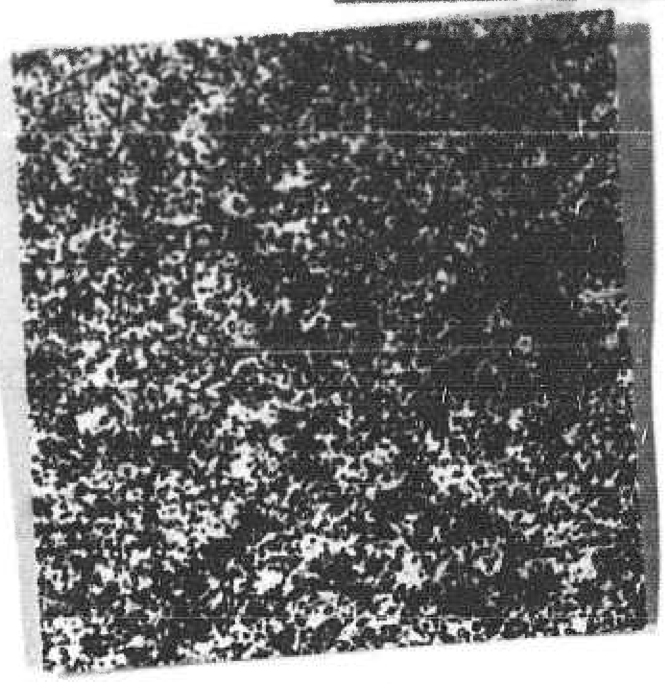
HARDNESS 28 R.C.

MAGNIFICATION 700X

ETCHED: Picral + Nital.

Photomicrograph M48

STRUCTURE OF BODY.



Spheroidal carbides in
a matrix of ferrite
and tempered martensite.

HARDNESS 35 R.C.

MAGNIFICATION 850X

ETCHED: Picral + Nital.

Photomicrograph M45

STRUCTURE OF BASE RING.

Spheroidal carbides in
a matrix of ferrite.

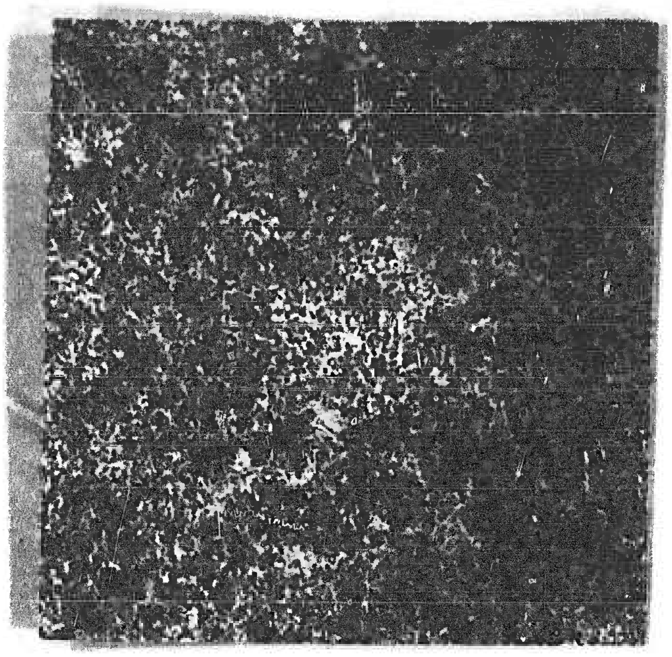
HARDNESS 20 R.C.

MAGNIFICATION 850X

Photomicrograph M44

MICROSTRUCTURE OF JAPANESE 8" PROJECTILE.

STRUCTURE OF CAP.



Spheroidal carbides in a matrix of tempered martensite.

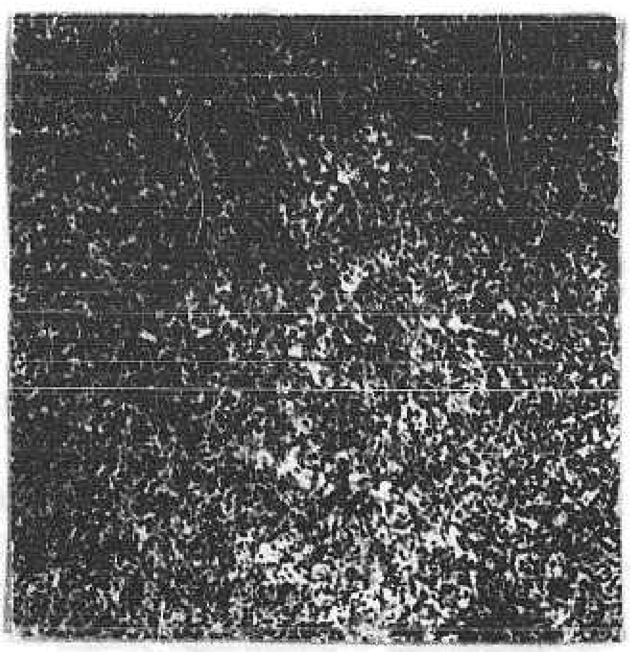
HARDNESS 50 R.C.

MAGNIFICATION 850X

ETCHED: Picral + Nital

Photomicrograph M42

STRUCTURE OF NOSE INTERIOR



Spheroidal carbides in a matrix of tempered martensite.

HARDNESS 40 - 45 R.C.

MAGNIFICATION 850X

ETCHED: Picral + Nital.

Photomicrograph M43

(D) HARDNESS SURVEY.

A systematic hardness survey was made on the polished ground surface of the slices shown in Fig. 4, NPG Photo No. 630 (APL). Results are given by hardness contours on a scaled cross section of the projectile included in NPG Drawing 101 (APL). (Inside of back cover.)

The cap is seen to be uniformly hardened to 50 R.C. (67 Shore). The nose has been decrementally hardened to 50 R.C. (67 Shore) on the surface, and 40 R.C. (55 Shore) at the cavity, while the body and base ring are 35 R.C. (50 Shore) and 30-20 R.C. (45-35 Shore) respectively. The base plug is 25 R.C. (40 Shore).

(E) MICROSTRUCTURE AND INDICATED HEAT TREATMENT

The microstructures as shown in photomicrographs M42 to 48, are typical of quench and tempered steels of this analysis and indicated hardness. It is evident that this projectile has been decrementally hardened and then base drawn.

The following heat treatment is deduced from the microstructure and the hardness survey.

(A) CONDITIONING TREATMENT.

(1) Soak at 1500°F followed by a timed water quench.

(2) Draw at 1200°F followed by a water quench to cold.

(B) HARDENING TREATMENT.

(1) Immersion in a lead pot at 1450°F to within one inch of base for approximately 30 minutes, followed by a timed water quench.

(2) Draw at 600° - 650°F.

(3) Base draw by slow immersion at 1100°F in a lead pot, base first, to within four inches of nose, followed by a water quench to cold.

The following heat treatment is indicated for the cap:

HARDENING TREATMENT.

(1) Heating to 1450°F, followed by a timed water quench.

(2) Draw at 600° - 650°F; water quench.

The following heat treatment is indicated for the base plug:

SPHEROIDIZING TREATMENT.

(1) Heat to 1450°F and water quench.

(2) Draw at approximately 1000°F.

TABLE A

TABULATION OF CHEMICAL ANALYSIS OF FUZE COMPONENTS

Component	Chemical Analysis +							
	C	P	S	Mn	Si	Cr	Ni	V
Fuze Adapter	.30	.010	.007	.48	.22	.67	3.60	NT
Fuze Body	.32	.021	.026	.76	.19	.75	4.60	.09
Firing Pin	.29	-	-	.12	.10	12.0	1.95	.04
Spacer	-	-	-	.70	.23	.51	3.75	.08
Booster Adapter	.31	.010	.015	.62	.22	.72	2.85	.06

	Cu	Zn	Sn	Ni	Pb	Al	Fe	Mn
Impact Shear Sections	59.85	35.10	.73	.09	.013	1.08	1.62	1.36
Set Back Plate	59.85	35.10	.73	.09	.013	1.08	1.62	1.36
Locking Plug	58.40	38.20	1.28	NT	.019	0.36	0.23	1.28
Firing Train	*	*	Tr	NT	T	T	T	T
Cast Metal (See Table B)	*	*	>Tr	Tr	NT	Tr	Tr	Tr

Spectrochemical Analysis.

Tr = Trace
NT = No Trace
* = Predominant.

+ The steel analysis reported here have been obtained spectrochemically with the exception of those of carbon, phosphorus, and sulphur, which were determined by standard chemical procedures. No traces of molybdenum, tungsten, titanium, copper, boron or zirconium were found in any of these steels.

TABLE B

TABULATION OF THE HARDNESS AND MICROSTRUCTURE OF FUZE COMPONENTS.

Component	Hardness	Microstructure
Fuze Adapter	28 R.C.	Quench and temper; carbides in ferrite.
Fuze Body	26 R.C.	Quench and temper; carbides in ferrite.
Firing Pin	30 R.C.	Quench and temper; carbides in ferrite.
Spacer	35 R.C.	Quench and temper; carbides in ferrite.
Booster Adapter	30 R.C.	Quench and temper; carbides in ferrite.
Impact Shear Sections	91 R.B.	Alpha in a Beta matrix; structure formed by furnace cooling a manganese bronze.
Set Back Plate	91 R.B.	
Locking Plug	86 R.B.	
Firing Train	88 R.B.	
Cast Metal *	--	Primary Alpha in a matrix of small Alpha and Beta grains; structure formed on chill freezing.

* Note: The distribution of components in the microstructure indicates that this alloy has a nominal composition of approximately 38% zinc; the presence of tin (spectrochemically) in appreciable amount makes it quite certain that the alloy is a Tobin bronze which is widely used as brazing rod. Tobin bronze is a carefully processed Muntz metal containing .5 to 1% tin with approximately 38% zinc and the remainder copper.

III INVESTIGATION OF FUZE.

(A) RECONSTRUCTION

The fuze, while considerably damaged by detonation, was found to be complete in all of its component parts. Fig. 5, NPG Photo No. 664 (APL) shows a deep acid etched cross section and NPG Drawing 102 (APL) is a reconstruction of this fuze. All component parts are indicated and dimensioned on this drawing. While slight discrepancies may possibly exist in some of the indicated contours, it is believed that this drawing is an accurate representation of the fuze assembly.

(B) TABULATION OF CHEMICAL ANALYSIS, HARDNESS AND MICROSTRUCTURE OF COMPONENTS.

Tables A and B list the chemical analyses hardness and microstructure of the fuze components.

(C) DISCUSSION OF FUZE.

ASSEMBLY. This fuze, an impact delay action type, combines extreme simplicity of design with novel features of assembly.

The close proximity of the firing point to the primer cap in this fuze, necessitates that the firing pin be accurately positioned and firmly held in that position. These desiderata are accomplished by a brazing operation using a molten Tobin bronze (see Table B for note) to effect a union between the brass locking plates and the knob on the firing pin. See Fig. 8, NPG Photo No. 662 (APL) in Addenda.

The actual mechanical operation of assembly has been deduced to be as follows:

(1) Inserting of firing pin into taper hole.

(2) Placing of five impact shear sections into position around firing pin knob.

(3) Placing of setback retainer plate into position, punching of the five retaining pin holes, and insertion of the retaining pins.

(4) Screwing of locking plug into position.

(5) Pouring molten Tobin bronze (probably

NPG PHOTO NO. 664 (APL) - Examination of Metals from Enemy Weapons.
Fuze Adaptor and Fuze of Japanese 8-inch projectile; hot acid etched
to show detail.
15 February, 1943.

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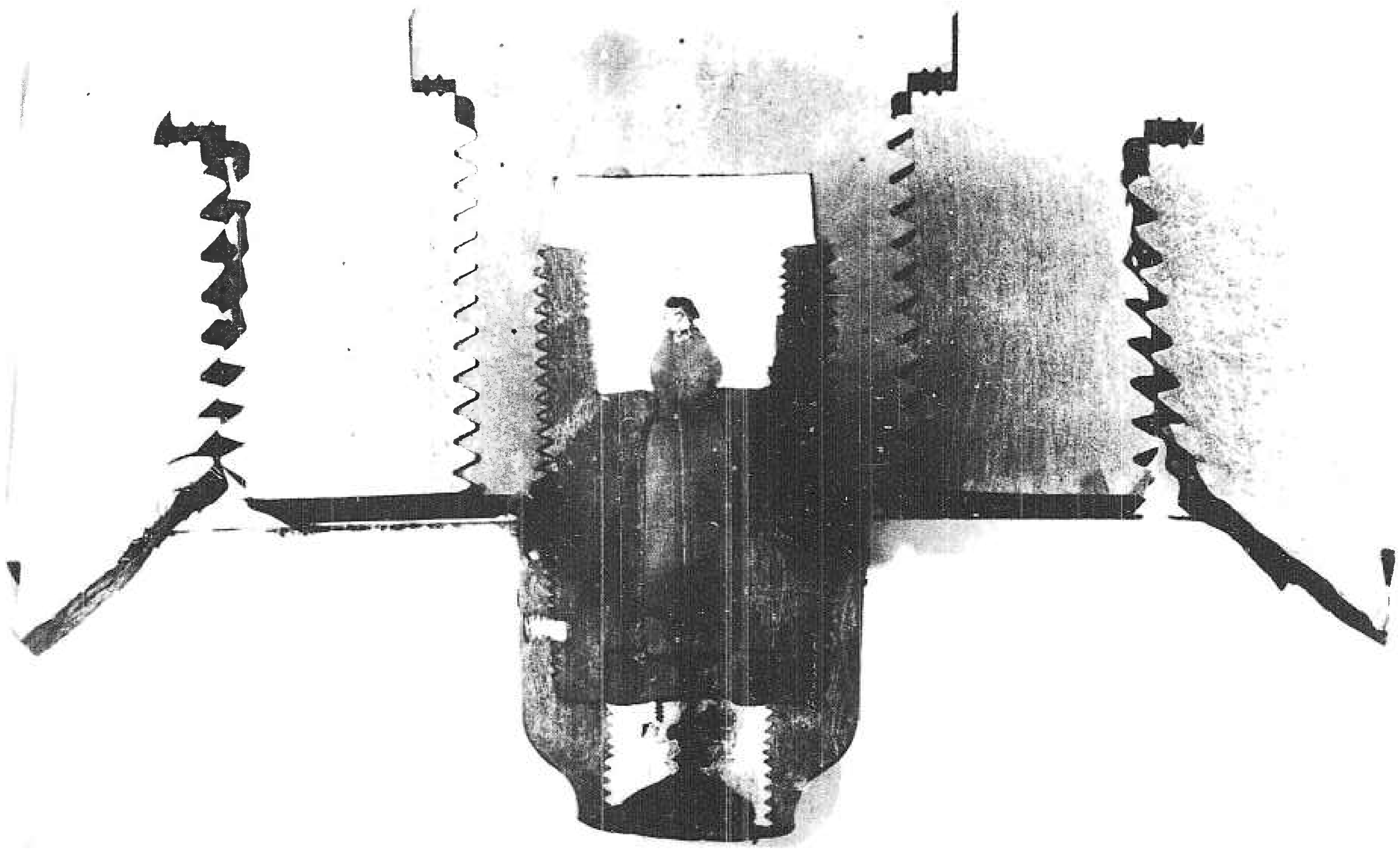
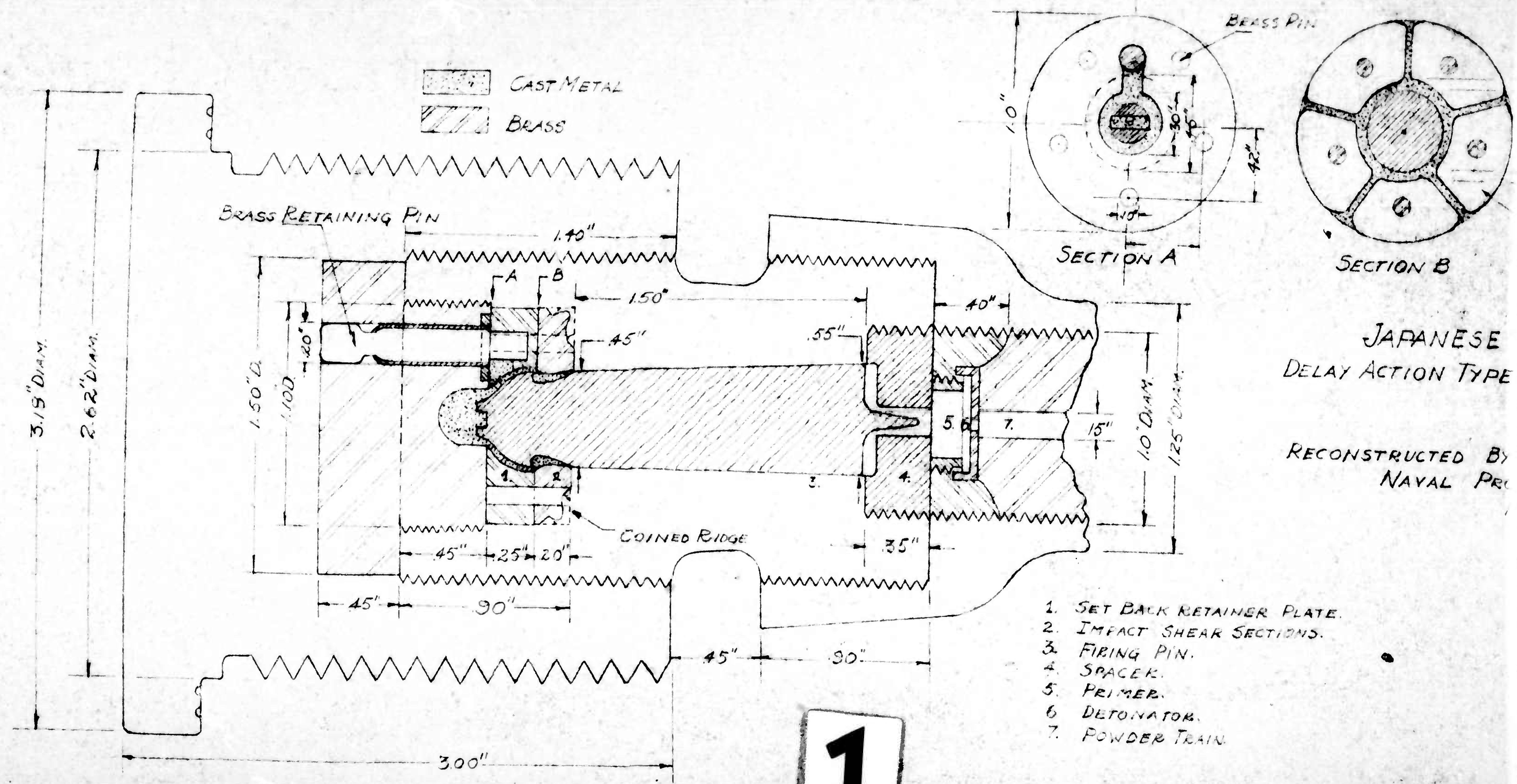




1

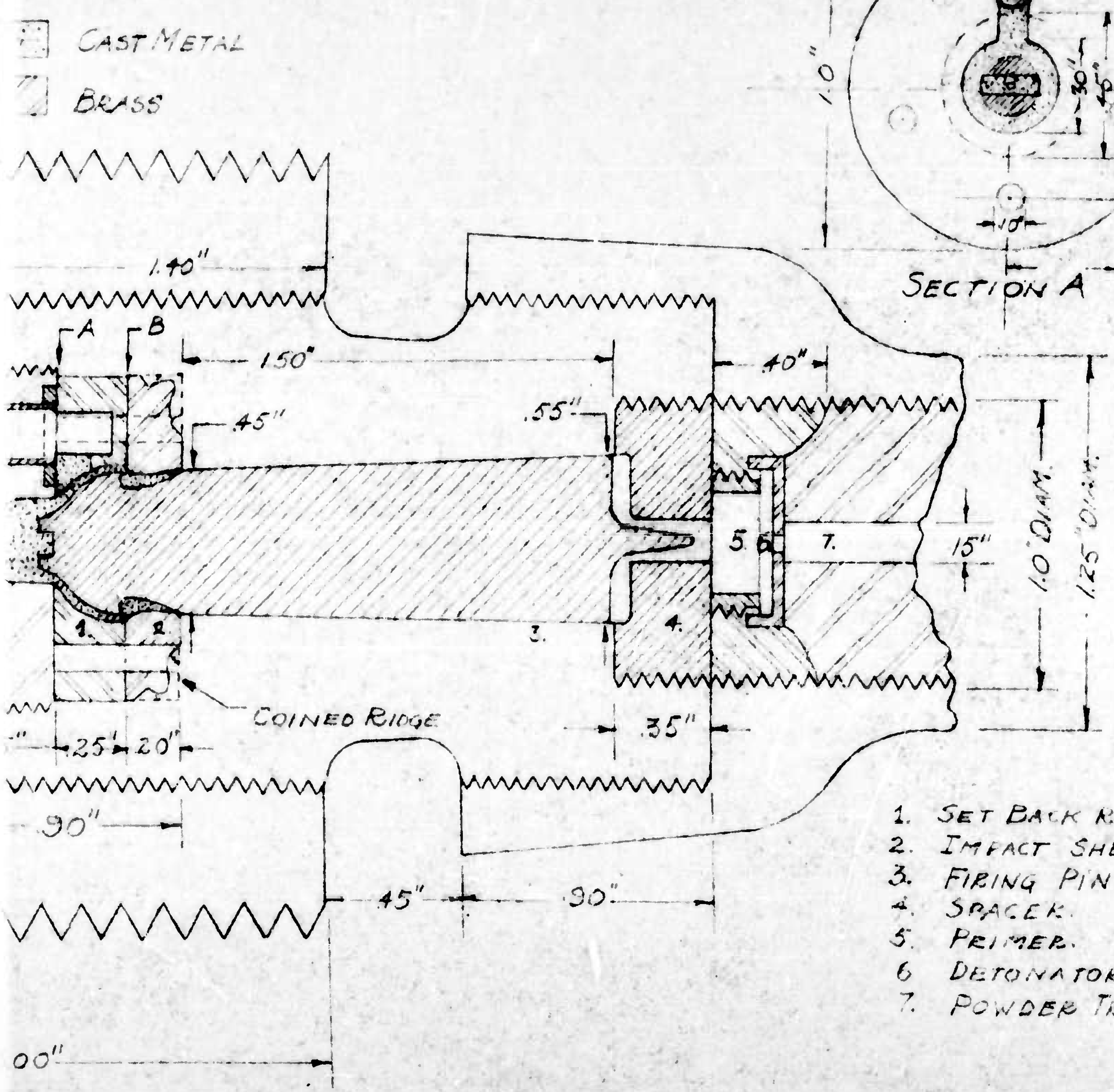
JAPANESE

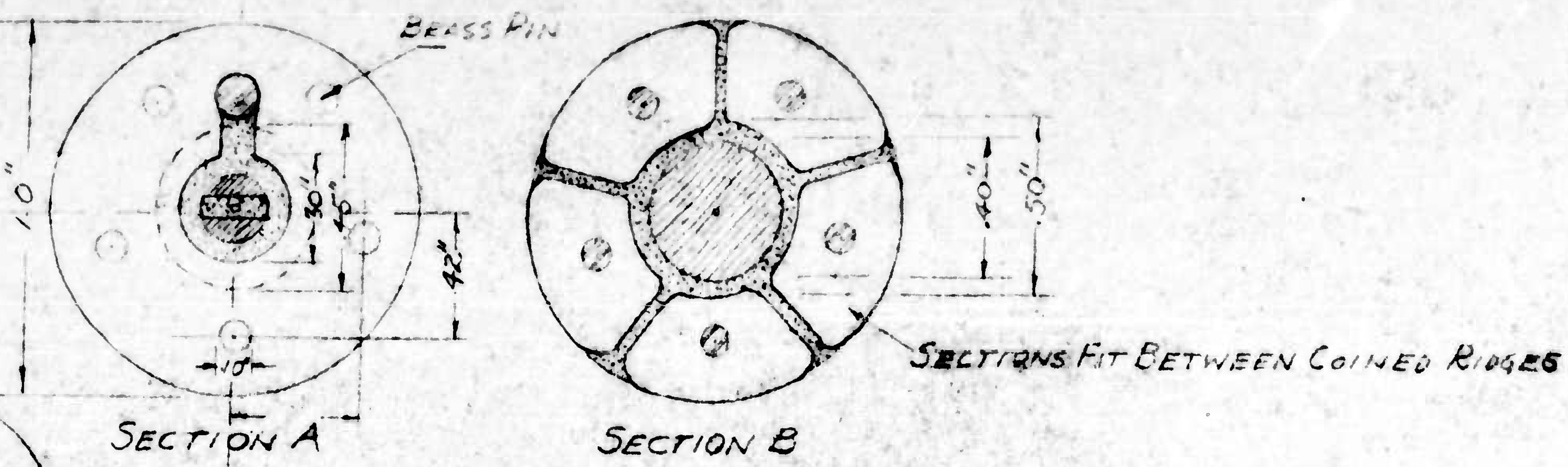
DELAY ACTION TYPE

RECONSTRUCTED BY

NAVAL PRO

1. SET BACK RETAINER PLATE.
2. IMPACT SHEAR SECTIONS.
3. FIRING PIN.
4. SPACER.
5. PRIMER.
6. DETONATOR.
7. POWDER TRAIN.





Japanese Base Detonating Fuze

Delay Action Type for 8 Inch Common Projectile

Reconstructed by the Armor & Projectile Laboratory
Naval Proving Ground - Dahlgren, Va
16 February 1943

1. Set Back Retainer Plate.
2. Impact Shear Sections.
3. Firing Pin.
4. Spacer.
5. Primer.
6. Detonator.
7. Powder Train.

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N.P.G. - DWG. - 102 A.P.L.

super-heated to 12-1300°F) into the large locking pin hole (of locking plug).

(6) Press-inserting of large locking pin while metal is still molten thus forcing the molten metal to fill all interstices in the assembly.

(7) Inserting of firing pin - primer spacer.

(8) Assembling into fuze and booster adapters.

It is suspected that pouring of this molten alloy around the firing pin knob would have a highly detrimental effect on the mechanical properties of the steel. Steels of the analysis of the firing pin show temper brittleness and cannot be allowed to cool slowly from temperatures above 600°C without the subsequent impairment of their mechanical, and particularly of their impact properties. Such a condition existing in this fuze should be considered extremely dangerous. That such a condition did exist was verified by the brittle fracture observed when the knob of the second fuze fractured on disassembly. See ADDENDA and Fig. 8, NPG Photo No. 662 (APL).

ACTION. This fuze possesses an action essentially similar to that of a shear pin, but in a form which makes use of shear plates or annuluses instead. When the gun is fired the firing pin is restrained from moving backward on setback by the bearing taper, and the setback retainer plate in the knob locking assembly. See Drawing 102 (APL).

In flight the pin cannot creep forward since it is locked securely in place by cast metal.

On impact the firing pin moves forward and having considerably mass exerts sufficient force through the knob to shear past the cast metal locking it in place. The pin is then free to strike the primer setting off the detonator and the delay action powder train and consequently the main charge. It must be concluded that this fuze requires a relatively heavy impact to make it function.

SAFETY. Obviously such a fuze makes a sacrifice of safety in the interest of positive action and simplicity. The shear plate arrangement can be considered to be only partially bore-safe; any accidental deceleration may conceivably cause the firing pin to creep forward and strike the primer - the fuze is essentially armed at all times.

NPG PHOTO No. 660 (APL) - Examination of Metals from Enemy Weapons. Report No. 5[illegible]. Engravings on the bourrelet of an 8-inch Japanese Projectile. (DE 403).
15 February, 194[illegible].

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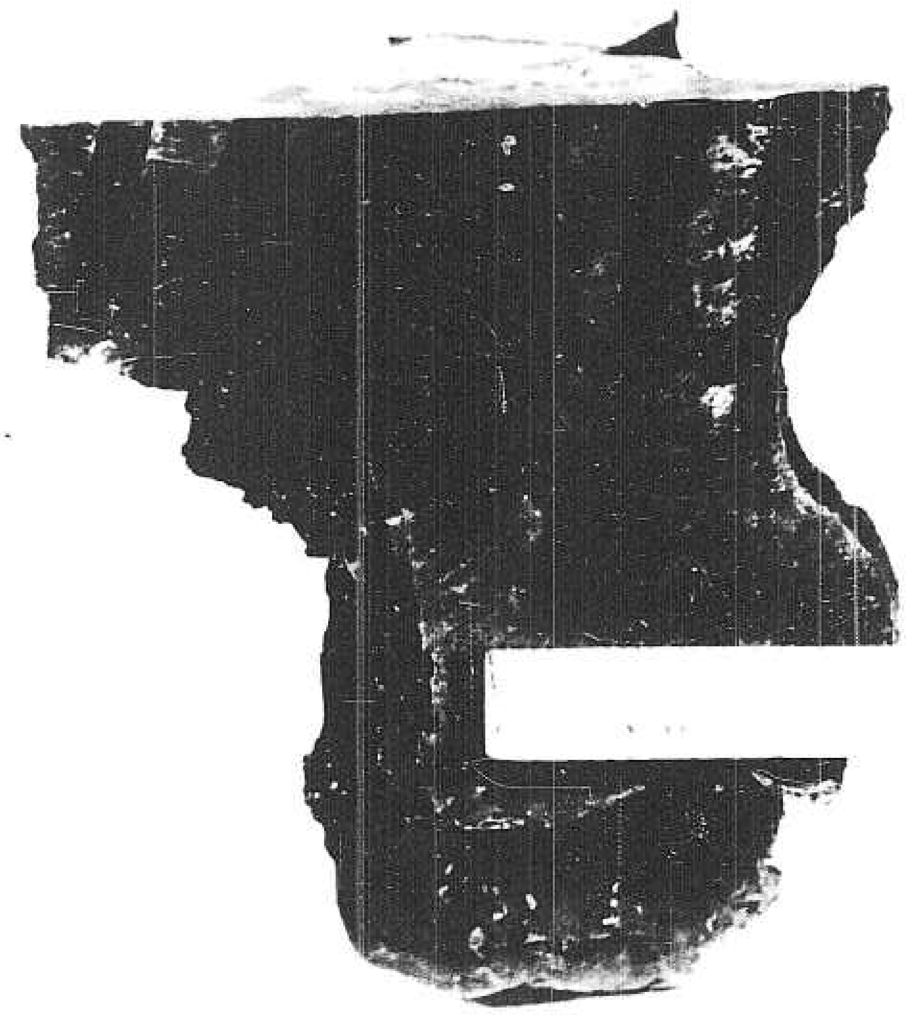

TABLE C

COMPARISON OF JAPANESE 8-INCH PROJECTILE WITH SOME 8-INCH COMMON PROJECTILES OF THE UNITED STATES NAVY.

			WEIGHTS (Pounds)									DIMENSIONS (Inches)				
Mark	Mod.	Date	Proj. Comp.	Charge	%	Body	Cap	%	Plug	Wind-shield	Band	Body	Bands	Bour-relet	Total Length	Boat Tail
14	1	1928	260	10.91	4.2	207.68	12.14	4.65%	10.58	9.30	6.80	24.43	3.30	1.62	36	None
12	1	1928	260	11.46	4.4	212.39	No Cap		15.85	10.92	6.79	26.187	3.30	1.62	36	None
15	1	1928	260	11.46	4.4	182.02	28.46	11%	13.59	7.44	6.60	24.85	5.30	1.62	36	None
17	1	1929	260	10.38	4.0	214.41	No Cap		15.85	9.98	6.79	24.60	3.30	1.62	36	None
17	3	1932	260	10.38	4.0	209.70	9.35	3.6%	11.60	9.16	6.50	25.40	3.30	1.62	36	None
17	4	1934	260	10.38	4.0	225.91 (Body & Cap)	-	-	13.00	1.53	6.79	25.78	3.30	1.62	28	None
Japanese			251.2	17.6	7%	196	7.9	3.15%	21.2	2.5	3.50	25.6	2.25	2.50	30	6°-45'

TABLE D

COMPARISON OF JAPANESE 8-INCH GUN WITH SOME UNITED STATES 8-INCH NAVAL GUNS

Gun	Year	Calibers	Rifling	No. of Grooves	Grooves per Inch of Cal.	Twist Rev./Cal.	Angle of Twist	Width of Land	Width of Groove	Depth of Groove % of Cal.	Angle of Driving Edge	Angle of Non-Driving Edge	Radius on Driving Edge	Radius on Non-Driving Edge
Mark D	1942	35	Ribbed Uniform	64	8	R.H.1-25	7°10'	.15"	.20	.07"-.875%	74°	74°	.01"	.01"
Mark A	1932	35	Ribbed Uniform	64	8	R.H.1-25	7°10'	.15"	.20	.07"-.875%	74°	74°	.01"	.01"
Mark XII-Mod. 1	1936	55	Ribbed Uniform	64	8	R.H.1-25	7°10'	.15"	.20	.07"-.875%	74°	74°	45° Chamfer	45° Chamfer
Mark XIV-Mod. C	1935	55	Ribbed Uniform	64	8	R.H.1-25	7°10'	.15"	.20	.07"-.875%	74°	74°	.01"	.01"
Japanese	-	-	Hook-Section Uniform	46	5.8	R.H.1-21	8°30'	.16 ±.005"	.30 ±.005"	.08±.005" 1%	85-90° (Est.)	58°*	.02" (Approx.)	.05" (Approx.)

R.H. = Right Hand.

* Slope of chord of large radius fillet.

No provisions have been made for detonator safety. If the detonator should be accidentally set off, the main charge would be exploded.

IV DISCUSSION OF PROJECTILE

The most striking feature of this projectile is the use of a flat nose and a relatively insecurely fastened conical cap. Also worthy of note are the use of a high percentage of filler, two rotating bands and boat tailing. The most important characteristics are compared in Table C to those of various 8-inch common projectiles used by the United States Navy.

The design of this projectile seems excellent for conventional use against lightly armored targets; however there is the possibility that this projectile may also have been designed for use against heavily armored vessels by underwater attack of their light armor. In such an attack the windshield is ripped off, thus also removing the cap and transforming this capped projectile to a flat nosed projectile. Such a design could also explain the use of a relatively insensitive fuze, which would prevent detonation on impact with water.

V CHARACTERISTICS OF GUN.

Fragments from the bourrelet carried very sharply defined engravings of the rifling .004"±.001" deep; see Fig. 6, NPG Photo No. 660 (APL). Measurements of these engravings together with other measurements taken from the engravings on the rotating bands (which were excellently preserved) were used to determine a number of muzzle characteristics of this gun. These characteristics, together with comparisons to those of various United States 8-inch naval guns, are are given in Table D. For calculations see Appendix B.

The use of two rotating bands and the clear cut engraving left on them indicates that this gun had uniform twist. The deep grooves (1% of caliber is considered maximum in general usage) indicates a high pressure gun with high rotational velocity for the projectile.

VI APPENDIX.

(A) PROJECTILE WEIGHT CALCULATIONS.

These calculations to determine the weights and capacity of this projectile are based on the dimensions given in NPG Drawing 101 (APL). The density of the steel is taken as .283 lbs. per cu. in.

Weight of Charge. The forward portion of the cavity can be assumed to be a volume generated by the revolution of one-half of an ellipse about its major axis (prolate spheroid). The rear portion of the cavity is known to be a cylinder.

$1/2$ Volume of prolate spheroid $= 1/2 \times \frac{4}{3} \times \pi \times 7.25 \times 2.885^2 = 125$ cu. in.

Volume of cylinder $= \pi r^2 l$

$V = \pi \times 2.875^2 \times 8.25 = 214$ cu. in.

The volume of the fuze is assumed to be 9 cu. in. hence the total volume occupied by the charge is

$125 + 214 - 9 = 330$ cu. in.

Assuming the filler to be explosive "D" having a density of .0535 lbs. per cu. in., the total weight of the bursting charge is then found to be $.0535 \times 330 = 17.6$ pounds.

Weight of Base Plug. Volume of base plug $= \pi r^2 t$

$= \pi \times 2.875 \times 2.875^2 = 75$ cu. in

Weight of base plug $75 \times .283 = 21.2$ pounds.

Weight of Cap. The cap is assumed to be a cone with a height of 2.75 inches and a base of 6.25 inches (allowance is made on the base to correct for actual curvature on the sides).

$V = 1/3 \pi r^2 h$

$= 1/3 \times \pi \times 3.125^2 \times 2.75 = 28$ cu

Weight $28 \times .0283 = 7.9$ pounds.

Actual weight of cap with a few chipped fragments missing was 7.5 pounds.

Weight of projectile Body. The body of the projectile for a distance of 18.125 inches from the base is known to be a cylinder. The volume $V_C = \pi r^2 l$

$$V_C = \pi \times 4^2 \times 18.125 = 915 \text{ cu. in.}$$

The forward portion of the projectile can be assumed to be a prolate spheroid with axis of 7.5 and 3.75 inches.

$$V_{p.s.} = 1/2 \ \frac{4}{3} \pi a \cdot b^2$$

$$= 1/2 \ \frac{4}{3} \pi \, 7.5 \times 3.75^2 = 221 \text{ cu. in.}$$

The total volume of the projectile body is then 915 plus 221 minus 75 (base plug) minus 330 (cavity) minus 38 (cap) or 694 cu. in. The weight of the body is then

$$694 \times .283 = 196 \text{ pounds.}$$

Weight of Windshield. It is assumed that the volume of the windshield is made up of a solid bounded by two cones 8 and 7.625 inches high and with diameters 6.125 and 5.75 inches respectively. This volume is 9 cu. in. The weight of the windshield is then

$$9 \times .283 = 2.5 \text{ pounds.}$$

Weight of Rotating Bands. The volume of the bands is made up of two rings each having a volume $V = 2\pi r l \, (a \times b)$ where a and b are the thickness and width of the rings.

$$V = 2\left\{ \pi \, 2 \times 4 \times (.19 \times 1.125) \right\} = 10.8 \text{ cu. in.}$$

The weight of the bands are then

$$10.8 \times .32 = 3.5 \text{ pounds.}$$

Total Weight of Projectile.

Projectile Body	196. pounds
Cap	7.9
Base Plug	21.2
Windshield	2.5
Rotating Bands	3.5
Estimation of Fuze	2.5
Bursting Charge	17.6
Total Weight	251.2 pounds.

APPENDIX B - CALCULATION OF GUN CHARACTERISTICS.

Angle of the Non-Driving Edge. The angle of the non-driving edge is formed by the hypotenuse and base of a triangle having a base equal to the length of the hook slope and an altitude equal to the depth of groove. Actually this represents the chord across the existing large radius fillet,

$$\tan \theta = \frac{.08}{.05} = 1.60$$

$$\text{angle } \theta = 58^{\circ}.$$

Grooves per inch. Five grooves were measured in 2.7 inches.

$$\frac{\text{Total number of grooves}}{2\pi \times 4} = \frac{5}{2.7}$$

Total number of grooves = 46

Number of grooves per inch of caliber $\frac{46}{8} = 5.8$

Twist in Calibers per Revolution. Measurement of the slope of the bourrelet engravings was $.15 \pm .005$ inches per inch. The reference normal was taken as parallel the lathe marks on the projectile. The number of calibers per revolution then equal to

$$\frac{1}{8} \times \frac{2\pi 4}{.15} \text{ or } 21.$$

The angle of twist θ = has a tangent equal to $\frac{\pi}{21}$ =

.1495 or 8.5°.

NPG PHOTO NO. 662 ([illegible]) - Examination of Metals from Enemy Weapons. Fuze assembly; note that the firing pin-head has fractured transversally as the result of separating the retaining units. Note that cast metal has flowed [illegible] the firing pin-head (left side) and between the impact shear sections [illegible] making a crazed assembly locking the firing pin rigidly in place. The locking pin is seen above [illegible] hole in the locking plug.
23 February, 1943.

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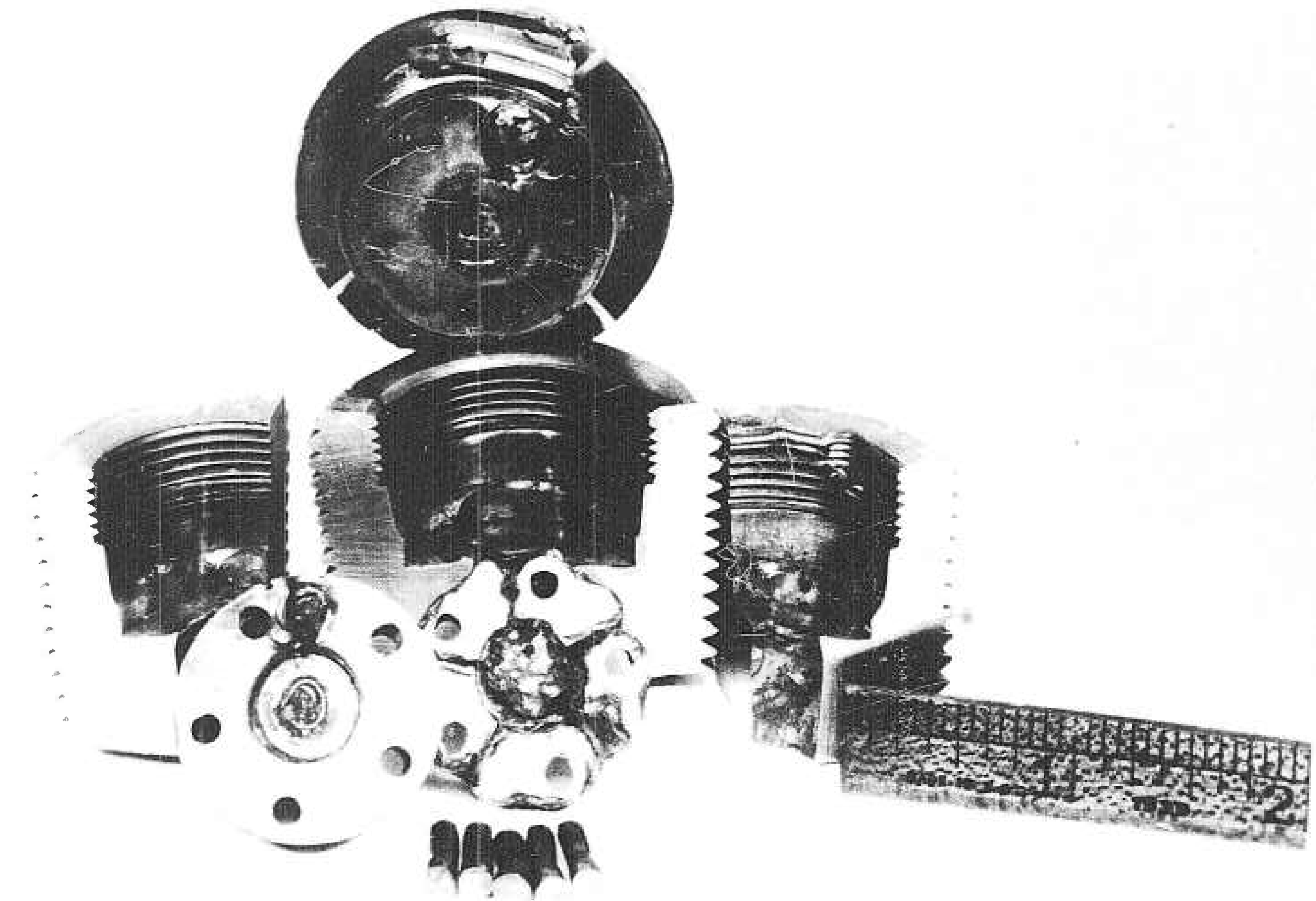

NPG PHOTO NO. 662 (APL) - Examination of Metals from Enemy Weapons. Fragments of a Japanese 8-inch common projectile. The fragment in the left foreground was identified as Homogeneous Armor Plate from the ship. CEE494.
23 February, 1943.

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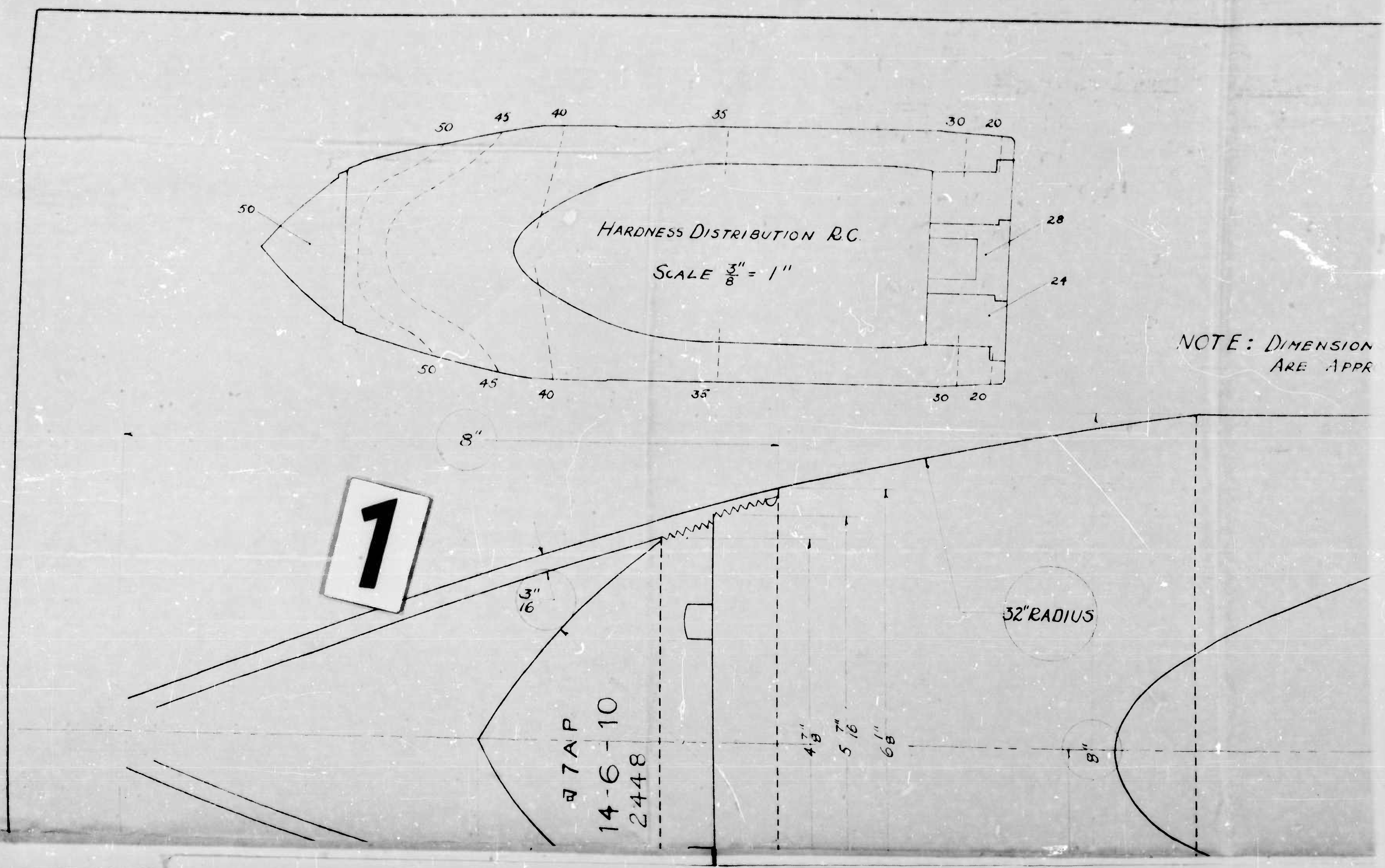
VII <u>ADDENDA</u>.

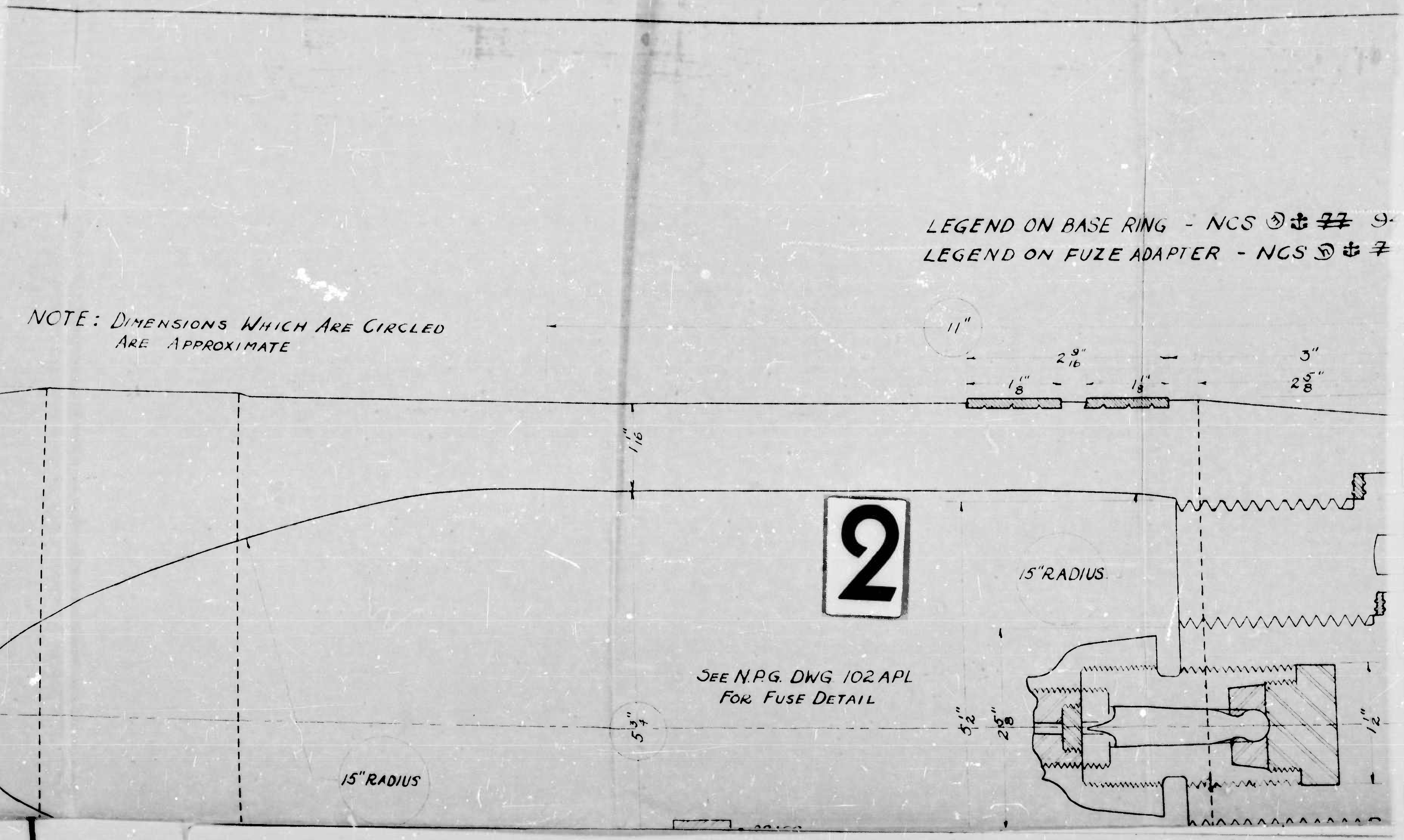
After completion of this report fragments were received of a projectile which had struck the U.S.S. SOUTH DAKOTA; Fig. 7, NPG Photo No. 661 (APL) shows the condition of these fragments when received. A piece of homogeneous armor of approximately 3-inch thickness was found among these fragments. The cap was not recovered.

The fragments were identified as belonging to a projectile identical to the one herein described and confirmed the reconstruction of this projectile and fuze. Only one minor difference could be found; the head of the firing pin in the second fuze recovered was found to be blunt instead of pointed as shown in NPG Drawing 102 (APL) of the first fuze. All other component parts and methods of assembly were found to be identical. Fig. 8, NPG Photo No. 662 (APL) shows this fuze following disassembly.

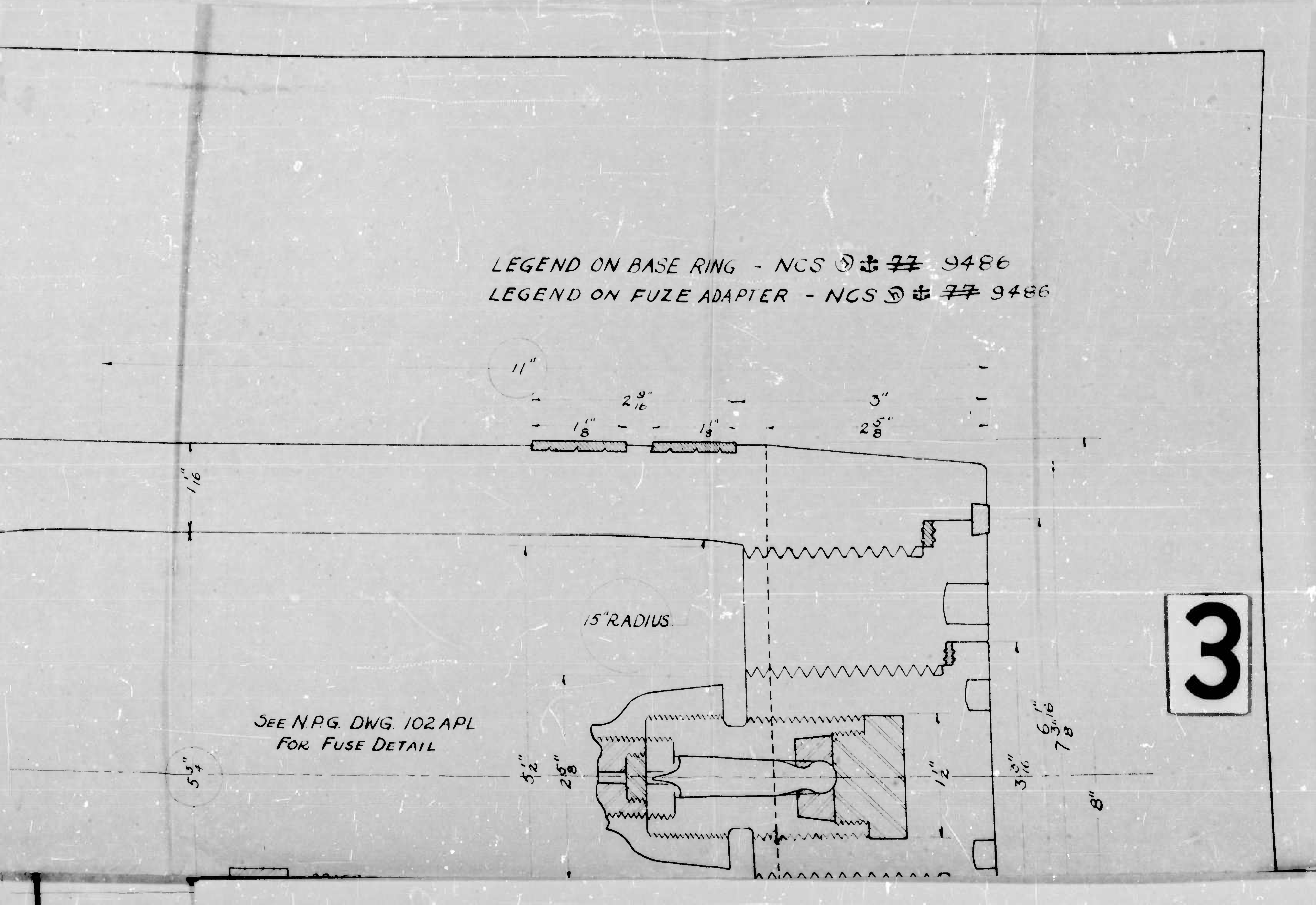
The following markings were found on the booster adapter

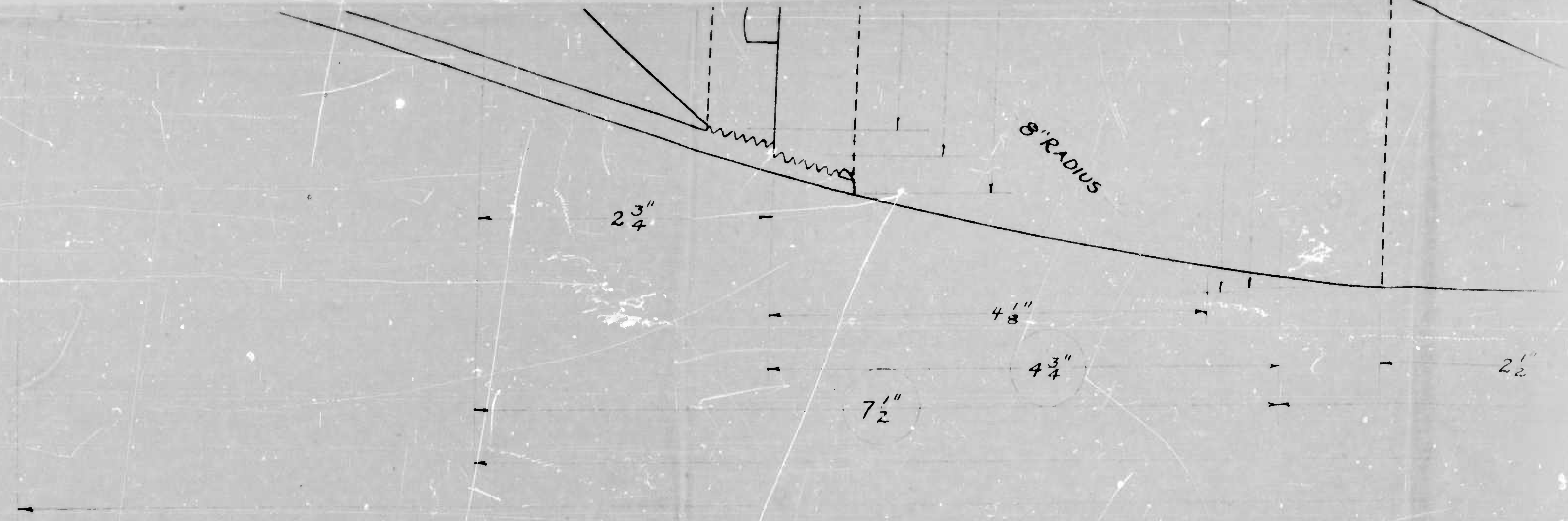
IV 実 39387 予 15[illegible]3.


HARDNESS DISTRIBUTION R.C.
SCALE 3/8" = 1"
50
45
40
35
30
20
28
24
NOTE: DIMENSION
ARE APPR
8"
3/16"
32" RADIUS
14-6-10
2448
4 7/8"
5 7/16"
6 1/8"
1



LEGEND ON BASE RING - NCS ~~77~~ 9
LEGEND ON FUZE ADAPTER - NCS 7
NOTE: DIMENSIONS WHICH ARE CIRCLED
ARE APPROXIMATE
11"
2 9/16"
3"
1 1/8"
1 1/8"
2 5/8"
1 1/16"
2
15" RADIUS
SEE N.P.G. DWG 102 APL
FOR FUSE DETAIL
5 3/4"
5 1/2"
2 5/8"
1 1/2"
15" RADIUS


3
LEGEND ON BASE RING - NCS Ⓓ ⚓ ~~77~~ 9486
LEGEND ON FUZE ADAPTER - NCS Ⓓ ⚓ ~~77~~ 9486
11"
2 9/16"
3"
1 1/8"
1 1/8"
2 5/8"
1 1/16"
15" RADIUS
SEE N.P.G. DWG. 102 APL
FOR FUSE DETAIL
5 3/4"
5 1/2"
2 5/8"
1 1/2"
3 3/16"
6 1/16"
7 3/8"
8"

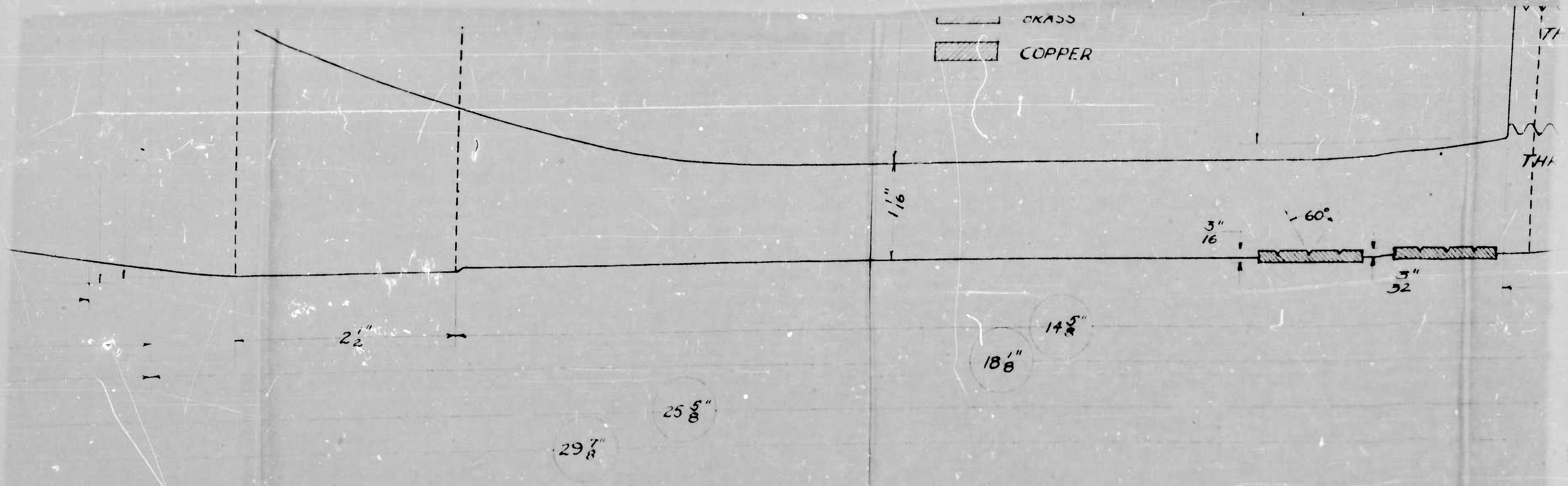


ANALYSIS

PROJECTILE BODY	.63C, .007P, .005S, .20MN, .25SI, 2.15CR, 2.80NI
CAP	.61C, .007P, .005S, .20MN, .25SI, 2.18CR, 2.87NI
BASE PLUG	.26C, .026P, .027S, .65MN, .30SI, .62CR, 3.33NI
FUZE ADAPTER	.29C, .010P, .007S, .40MN, .22SI, .67CR, 3.60NI
ROTATING BANDS & GASKETS	PURE COPPER

CA

4



2, 2.80 NI
, 2.87 NI
, 3.33 NI
, 3.60 NI

JAPANESE 8INCH COMM

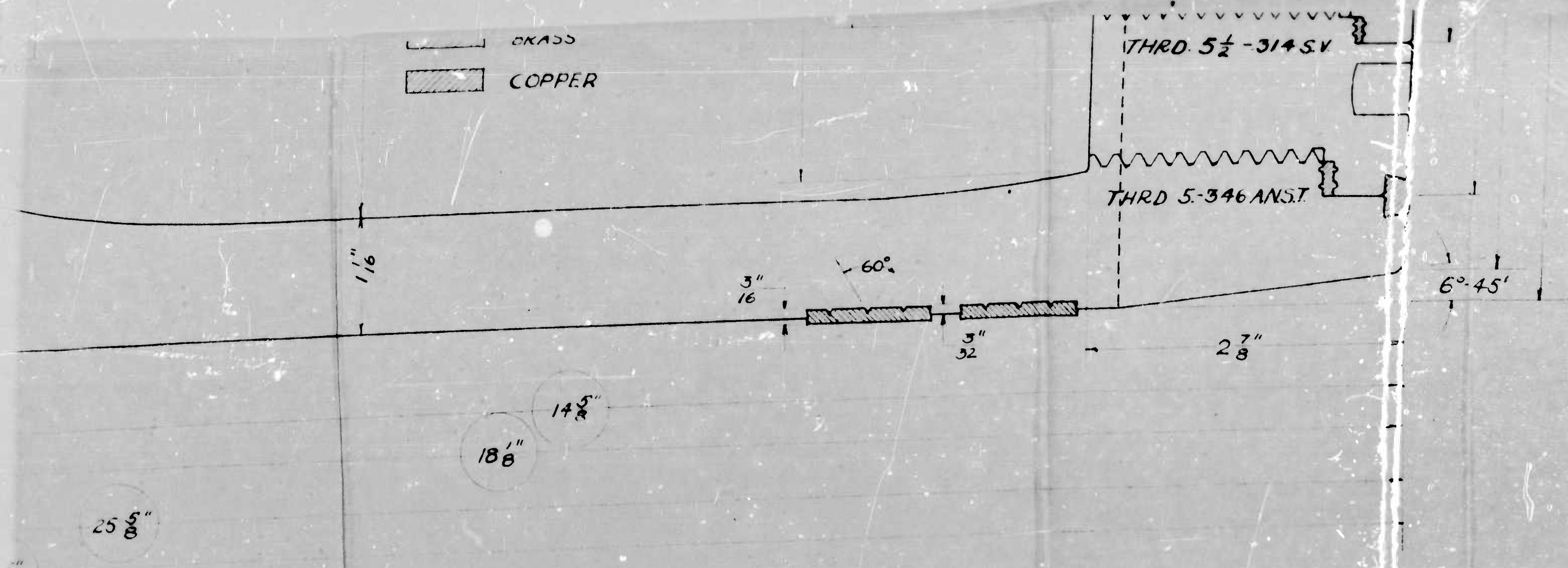
RECONSTRUCTED BY THE ARMOR &

NAVAL PROVING GROUND

16 FEBRUARY 19

CALCULATED WEIGHTS	LBS.	
PROJECTILE BODY	196.0	
CAP	8.0	
BASE PLUG	21.0	
WINDSHIELD	2.5	
ROTATING BANDS	3.5	
FUZE (ESTIMATED)	2.5	
BURSTING CHARGE (ASSUME D=1.48)	17.5	VOLUME 330 CU. IN.
PROJECTILE COMPLETE	251.0	

5



JAPANESE 8INCH COMMON PROJECTILE

EIGHTS	LBS.
BODY	196.0
	8.0
	21.0
D	2.5
BANDS	3.5
IMATED)	2.5
CHARGE (ASSUME D=1.48)	17.5
ILE COMPLETE	251.0

VOLUME 330 CU. IN.

RECONSTRUCTED BY THE ARMOR & PROJECTILE LABORATORY
NAVAL PROVING GROUND - DAHLGREN, VA.

16 FEBRUARY 1943

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WB

N.P.G. DWG. 101-APL